SECTION 22 CONNECTICUT

Hydrologic Analysis for Streamflow Augmentation Naugatuck River Watershed

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EXECUTIVE SUMMARY

This study was prepared at the request of the State of Connecticut Department of Environmental Protection (DEP). The DEP had requested that the U.S. Army Corps of Engineers examine the hydrologic capabilty of Corps flood control dams and reservoirs in the Naugatuck River basin to augment the summertime streamflows of the Naugatuck River in Waterbury, Connecticut for recreational and aesthetic purposes. No significant reduction in the flood control capabilities of the Corps dams would be allowed. Only the hydrologic impacts of utilizing Corps dams for flow augmentation purposes were to be thoroughly addressed in this study; non-hydrologic aspects are described in this report, but only at a cursory level.

The hydrologic examination found that significant flow augmentation could result by utilizing storage behind Thomaston Dam without significantly infringing upon its primary purpose of flood control. A seasonal pool of 6000 acre-feet could be utilized to augment streamflows in Waterbury by a continuous flow of 25 cubic feet per second through the summer months of June through September. The resulting increase in streamflow depth at Waterbury would be less than 0.5 feet. Only very minor storage could be utilized at other Corps dams in the Naugatuck River basin above Waterbury.

There are several non-hydrologic impacts that would likely occur with creation of a seasonal pool at Thomaston's normally dry-bed reservoir. The most significant impact would be a degradation in water quality upstream and downstream from the dam. Other impacts, however, include the flooding of public access facilities and a series of off-road vehicle trails.

Further study of the positive and negative aspects of the creation of a seasonal pool for flow augmentation purposes should occur before any changes are made in the project's operation.

Hydrologic Analysis For Streamflow Augmentation
Naugatuck River Watershed, Connecticut

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1. Purpose and Scope

The purpose of this report is to investigate the potential of utilizing Corps of Engineers reservoirs to augment summer (June - September) streamflows along the Naugatuck River in Waterbury, Connecticut without affecting the authorized flood control purpose of the projects. Summer streamflows in the Naugatuck River are relatively low as compared to the remainder of the year. The State of Connecticut considers increased summertime flows desirable in the interest of recreation, aesthetics and associated environmental concerns. The State recognizes, however, that the primary purpose of Corps reservoirs is flood control, and the seasonal use of an increment of flood control storage must not compromise the primary purpose of the project.

The report also provides a cursory assessment of requirements for the construction of weirs across the Naugatuck River in Waterbury in order to create a series of pools for aesthetic purposes.

2. Authority

This study was conducted at the request of the State of Connecticut, Department of Environmental Protection (DEP) under authority contained in Section 22 of the Water Resources Development Act of 1974 (Public Law 93-251) as amended "Planning Assistance to the States". The Section 22 program authorizes cooperation between the Corps of Engineers and the states in the preparation of plans for the development, use and conservation of water and related resources. The purpose and content of this study was developed during meetings between representatives of the Corps of Engineers and the Connecticut Department of Environmental Protection.

3. Prior Related Investigations

a. Drought Contingency Plan, Thomaston Dam Thomaston, Connecticut - Completed in June 1983, the report provides a potential plan of operation at the project during drought periods to respond to public needs. The report provides information concerning the reallocation of storage within specified limits, and discusses potential impacts of providing drought storage.

b. Hydropower Study, Reconnaissance Report, Thomaston Dam Thomaston, Connecticut - Completed in August 1982, the report investigated the feasibility of adding a hydroelectric generating facility to the Corps of Engineers flood control project. The report defined the problems and opportunities of developing hydropower and identified potential plans of development.

c. In August 1974, the Corps of Engineers established a temporary pool covering 35 acres behind Thomaston Dam for the purpose of collecting water quality data to evaluate the possibility of maintaining a permanent conservation pool at the project. The study was conducted in conjunction with the State of Connecticut, Department of Environmental Protection (DEP). During this same period, the DEP was attempting to establish a cold water fisheries on the Naugatuck River. Because of the adverse water quality conditions created by the impoundment at Thomaston Dam and their impact to the efforts to establish cold water fisheries in the Naugatuck River, the DEP requested the Corps to discontinue the study. The temporary pool was drained in October of 1977.

4. Watershed Description

a. General. The Naugatuck River is the largest and most important watershed of the Housatonic River and is shown on Plate 1. The general flow is southerly through Torrington, Thomaston, Waterbury, Naugatuck, Beacon Falls, Seymour, and Ansonia to Derby where it discharges into the Housatonic River, 12 miles above its mouth. The Naugatuck watershed is located primarily within the boundaries of Litchfield and New Haven Counties, with a small portion extending into Hartford County. The watershed has a maximum length and width of approximately 50 and 12 miles, respectively, and a total drainage area of about 312 square miles. The slope is rather uniform, about 14 feet per mile between the headwaters at Torrington and tidewater in Derby, CT. Drainage areas of the Naugatuck River at Thomaston, Waterbury, and Beacon Falls are approximately 97, 136, and 260 square miles, respectively.

b. Principal Tributaries. Principal tributaries to the Naugatuck River, their watershed area, water course lengths, and falls are listed in downstream order in Table 1.

c. Existing Dams and Reservoirs. There are seven Corps of Engineers constructed flood control dams within the Naugatuck River watershed. These projects significantly reduce flooding along the entire length of the Naugatuck River as they control 50 percent of the watershed's drainage area. Pertinent data for all projects is listed in Table 2 and project locations are shown on Plate 1.

d. Local Protection Projects. The Corps of Engineers has constructed four Local Protection Projects within the Naugatuck River basin. These projects provide Standard Project Flood (SPF) protection to areas within the basin which would otherwise still be prone to flooding despite the operation of the Corps flood control reservoirs. The Local Protection Projects in the basin are listed in Table 3.

TABLE 1

NAUGATUCK RIVER TRIBUTARIES

River or Tributary	Drainage Area (sq. mi.)	Length (miles)	Fall (feet)
West Branch	34	6	270
East Branch	14	9	729
Leadmine Brook	24	7	340
Branch Brook	23	4.5	250
Hancock Brook	16	10	330
Steel Brook	17	7	427
Mad River	26	6.5	450
Hop Brook	17	9	450
Bladen River	11	4.5	355
Little River	15	8.5	560

TABLE 2

NAUGATUCK RIVER WATERSHED
FLOOD CONTROL DAMS
PERTINENT DATA

Project	Drainage Area (sq.mi.)	Flood Control Storage Capacity Acre-feet	Flood Control Storage Capacity Inches	Owner
East Branch	9.3	4,350	8.8	State of Connecticut
Hall Meadow	17.2	8,600	9.3	State of Connecticut
Thomaston	97.2	42,000	8.1 *	Corps of Engineers
Northfield Brook	5.7	2,350	7.7	Corps of Engineers
Black Rock	20.4	8,450	7.8	Corps of Engineers
Hancock Brook	11.9	3,900	6.1	Corps of Engineers
Hop Brook	16.4	6,850	7.8	Corps of Engineers

* 8.1 inches from the 97.2 square mile gross drainage area and 10.4 inches from the 75.7 square mile net drainage area

TABLE 3

NAUGATUCK RIVER WATERSHED
LOCAL PROTECTION PROJECTS

Project	Constructed	Description
Ansonia	January 1973	Relocation and realignment of the river channel; construction of dikes, flood walls, highway gates and interior drainage facilities including pump stations.
Derby	January 1973	Construction of dikes, flood walls, railroad gates and interior drainage facilities including pump stations.
Waterbury/Watertown	November 1961	Construction of dikes, flood walls, and a railroad stoplog structure.
Torrington		
(East Branch)	September 1958	Channel straightening, deepening, and widening. State and local replacement of bridges.
(West Branch)	May 1960	Construction of concrete wall and channel modifications.

A hydrologic assessment of the flood control adequacy of the Torrington LPP conducted by NED in 1989 identified an apparent loss of flood protection. This loss appears to be significant at several locations along the local protection project and, therefore, additional in-depth hydrologic/hydraulic studies were recommended. Pending the outcome of these studies, seasonal encroachment into flood storage should not be considered at Hall Meadow or East Branch reservoirs.

5. Climatology

a. General. The climate of the Naugatuck River watershed is generally moderate, and the basin is subject to frequent, but short periods of heavy precipitation. The watershed lies in the paths of the "prevailing westerlies," which often include cyclonic disturbances that cross the country from the west or southwest and converge on the northeast. It is also exposed to occasional coastal storms, some being of tropical origin and of hurricane intensity, that travel up the Atlantic Seaboard.

b. Temperature. The average annual temperature in the Naugatuck River watershed is about 50 degrees F. Average monthly temperatures vary widely throughout the year. Temperature extremes vary from -25 degrees F., for a low, to a high of 105 degrees F. Freezing temperatures can be expected from the middle of November until the end of March. The mean, minimum, and maximum monthly temperatures at Waterbury in the center of the watershed, and at Bridgeport along the Connecticut coast, are summarized in Table 4.

c. Precipitation. The average annual precipitation is about 47 inches and is uniformly distributed throughout the year. Monthly and annual precipitation at Torrington and Bridgeport, Connecticut is shown in Table 5.

6. Streamflow

a. General. Average streamflow of the Naugatuck River at Waterbury is about 1.9 cubic feet per second (cfs) per square mile of drainage area, equivalent to about 25 inches of runoff per year or about 53 percent of average annual precipitation. Streamflow, however, is quite variable seasonally. Maximum streamflow rates on the main stem Naugatuck River at Beacon Falls have been as high as 400 cfs per square mile of drainage area (prior to construction of the system of flood control reservoirs) and lows approach 0.15 cfs per square mile, generally occurring in late summer or midwinter.

b. Streamflow Records. There are six USGS streamflow gaging stations in the Naugatuck watershed. Discharge records of these stations, particularly the two on the Naugatuck River (Thomaston and Beacon Falls), were used in this hydrologic assessment. Table 6 lists the six USGS gaging stations. When estimating flow durations, mean and low flows at Waterbury, the gaged record at Beacon Falls was utilized. The principal reason for adopting the gaged record at Beacon Falls as a

TABLE 4

NAUGATUCK RIVER WATERSHED
MONTHLY TEMPERATURES
(Degrees Fahrenheit)

Waterbury, Connecticut: 73 Years of Record

Month	Mean	Maximum	Minimum
January	27.7	73	-19
February	28.1	70	-25
March	37.1	87	- 7
April	48.2	92	11
May	59.4	96	24
June	67.9	101	33
July	72.7	105	41
August	70.6	104	35
September	64.0	103	25
October	53.4	94	17
November	42.3	84	2
December	30.9	70	-12
Annual	50.2	105	-25

Bridgeport, Connecticut: 80 Years of Record

Month	Mean	Maximum	Minimum
January	30.1	68	-14
February	30.4	70	-20
March	38.4	85	1
April	48.7	97	9
May	57.7	95	26
June	68.1	99	34
July	73.8	103	44
August	72.2	101	38
September	65.9	98	32
October	55.4	90	20
November	44.4	80	8
December	33.1	67	-12
Annual	51.5	103	-20

TABLE 5

NAUGATUCK RIVER WATERSHED
MONTHLY PRECIPITATION RECORDS
(In Inches)

Torrington, Connecticut: 41 Years of Record

Month	Mean
January	3.51
February	3.39
March	4.10
April	4.03
May	3.66
June	3.85
July	3.71
August	4.32
September	3.95
October	3.73
November	4.35
December	4.26
	46.86

Bridgeport, Connecticut: 41 Years of Record

Month	Mean
January	3.22
February	2.99
March	3.75
April	3.72
May	3.51
June	3.04
July	3.76
August	3.50
September	3.00
October	3.11
November	3.87
December	3.56
	41.03

TABLE 6

STREAMFLOW RECORDS
NAUGATUCK RIVER WATERSHED

Location of Gaging Station	Drainage Area (sq. mi.)	Period of Record (years)	Mean	Discharge (cfs) Maximum	Minimum
West Branch Naugatuck River Torrington, CT	33.8	33	58.4	3,180	0.3
East Branch Naugatuck River Torrington, CT	13.6	33	24.8	1,500	0.3
Naugatuck River Thomaston, CT	97.2	29	197.0	53,400*	6.6
Branch Brook Thomaston, CT	20.8	17	34.5	805	0.1
Hop Brook Naugatuck, CT	16.3	19	33.7	582	0.1
Naugatuck River Beacon Falls, CT	260.0	66	510.0	106,000*	40.0

* Peak discharges occurring prior to construction of flood control reservoir system

base was due to its extensive 66-year period of record. Also, analysis of this record, in particular low flow frequencies, would be more reliable than analysis of the 29-year record at Thomaston. The shorter gaged record at Thomaston could be more likely biased by the "1960's" drought years. In addition, a cursory review of the Naugatuck watershed map reveals more available storage in the tributaries between Thomaston and Beacon Falls which could tend to increase low flows. Therefore, estimated mean and low flows at Waterbury presented in this report were based on the analysis of Beacon Falls gaged record and flows at Thomaston are presented for information purposes.

c. Average Monthly Runoff. The average monthly runoff recorded at the Thomaston and Beacon Falls gages on the Naugatuck River are listed in Table 7. Average monthly runoff as recorded at Thomaston from 1961 to 1988 varies from about 202 cfs or 2.3 inches in May to 74 cfs or 0.8 inch in September. Average monthly runoff at Beacon Falls varies from 587 cfs or 2.3 inches in May to 231 cfs or 0.9 inches in September. Plate 2 graphically presents average monthly flows at these gages and the estimated monthly flows at Waterbury, CT which were determined based on analysis of Beacon Falls flow data. Table 7 also lists the estimated mean and minimum flows at Waterbury.

d. Flow Duration Curves. Annual flow duration and summer (June to September) flow duration curves (flow versus percent time equaled or exceeded) for the Naugatuck River at Thomaston and Beacon Falls were developed by using the USGS WATSTORE computer flow data. Annual flow duration data is shown in Table 8 and the summer season flow duration relationship is shown on Plate 3. Also shown on Plate 3 is the estimated flow duration relationship at Waterbury which was prorated from Beacon Falls gaging station by drainage area ratio. The developed flow duration curves illustrate the magnitude and variability of streamflow in the basin.

e. Low Flow Duration Frequencies. The Naugatuck River frequently experiences low streamflows of varying duration and severity. Quantitative information on the frequency and duration of seasonal low flows was developed using WATSTORE computer flow data for the two USGS gaging stations at Thomaston and Beacon Falls and are shown on Plates 4 and 5. As low flow periods are most common in the summer months, and it is the intent to augment streamflows during this period, low flow frequency curves were analyzed. The curves were developed using a Log Pearson Type III distribution of the summer (June to September) flow data. The 10 percent chance 7-day low flow, a commonly used seasonal low flow index, ranged from 0.13 cfs per square mile of drainage area at the Thomaston gage (13 cfs) to 0.25 cfs per square mile at the Beacon Falls gage (65 cfs). Estimated low flow duration frequencies for the summer season at Waterbury are shown on Plate 6.

7. Existing Flood Control Reservoirs

a. General. There are seven flood control reservoirs within the Naugatuck River watershed designed and built by the Corps of Engineers. These reservoirs are operated as a system to reduce flood damages along the length of the Naugatuck River. For the purpose of this study, the

TABLE 7

MONTHLY FLOWS
NAUGATUCK RIVER
(cfs)

	Thomaston, CT DA = 97.2 square miles 1961-1988			Beacon Falls, CT DA = 260 square miles 1919-1988		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum
January	221	757	31	592	2,307	118
February	251	776	57	588	1,436	204
March	418	785	177	1,020	2,227	459
April	402	966	103	974	2,467	273
May	02	413	75	587	1,163	225
June	160	658	34	392	1,973	122
July	80	331	18	240	957	73
August	69	429	18	230	2,920	72
September	74	472	14	231	1,301	68
October	106	467	21	281	2,480	55
November	161	413	24	435	1,890	64
December	224	709	51	559	1,660	113
Annual	197	300	77	510	830	237

	Estimated at Waterbury, CT DA = 136 square miles	
	Mean	Minimum
January	308	61
February	305	106
March	530	238
April	506	141
May	305	117
June	203	63
July	124	38
August	120	38
September	120	35
October	146	28
November	226	33
December	290	58
Annual	265	123

TABLE 8

ANNUAL FLOW DURATION

Percent Time Equaled or Exceeded	Thomaston Gage DA = 97.2 sq. mi. (cfs)	Beacon Falls Gage DA = 260 sq. mi. (cfs)
10	431.0	1,120
20	263.0	721
30	189.0	529
40	144.0	404
50	108.0	309
60	81.8	236
70	56.8	178
80	38.8	136
90	26.5	103
95	20.6	85

four reservoirs, Thomaston, Black Rock, Hancock Brook and Northfield Brook, were considered for flow augmentation at Waterbury. Due to reasons cited in Section 4, East Branch and Hall Meadow were not examined at this time. Also, Hop Brook was not included because it is located downstream of Waterbury. The following sections describe the dams and reservoirs considered in this assessment.

b. Thomaston Dam. The dam is located in Thomaston, CT on the Naugatuck River about 1.1 miles above Thomaston Center. The embankment consists of a rolled earth and rock-fill dam with a height above streambed of 142 feet.

The spillway is an L-shaped side channel-type located in rock on the left abutment. The 435-foot long ogee-shaped weir has its crest at elevation 494 feet NGVD. The outlet works consist of a gate chamber, control tower and operating house on the upstream side of the dam, and a 455-foot long and 10-foot diameter horseshoe-shaped conduit.

The dam provides for flood control only, with a total storage capacity of 42,000 acre-feet, equivalent to 8.1 inches of runoff from the gross drainage area of 97.2 square miles, or 10.4 inches from the net drainage area below East Branch and Hall Meadow Brook reservoirs.

c. Black Rock Lake. Black Rock Lake is located in Thomaston and Watertown on Branch Brook, about 2 miles upstream from the Naugatuck River. The dam embankment consists of a rolled earthfill and rock-faced dam with a height of 155 feet above the streambed.

The chute spillway is located in a rock cut along the right bank. The spillway weir is a low concrete ogee, 140 feet in length at elevation 520 feet NGVD. The outlet works consist of an intake channel, a concrete weir to maintain a permanent pool, a control tower on the upstream side of the dam, a 4 by 5 rectangular conduit, and an outlet channel.

The lake contains storage for flood control and recreation. The recreation pool at elevation 437 feet NGVD contains 305 acre-feet, equivalent to 0.28 inch of runoff. The flood control storage contains 8,450 acre-feet, which equals 7.8 inches of runoff from the 20.4 square mile drainage area.

d. Hancock Brook Lake

Hancock Brook Lake is located within the town of Plymouth, CT. The dam is situated on Hancock Brook about 3.2 miles upstream of its confluence with the Naugatuck River. The embankment consists of a rolled earth fill dam with a height of 57 feet above the streambed.

The spillway is an uncontrolled chute-type adjacent to the right abutment of the dam. The 100-foot long concrete crest is at elevation 484.0 feet NVGD. The outlet works consists of an inlet channel and a small U-shaped concrete weir to control the normal pool level.

The lake contains storage for flood control and recreation, and the 6-foot deep permanent pool contains 130 acre-feet of storage, equal to

0.2 inch of runoff. The flood control storage consists of 3,900 acre-feet, equivalent to 6.1 inches of runoff from the 11.9-square mile drainage area.

e. Northfield Brook Lake

The project is within the towns of Thomaston and Litchfield, with the dam located on Northfield Brook about 1.3 miles above its confluence with the Naugatuck River. The embankment is composed of rock slope protection and rolled earthfill with a maximum height of 118 feet above the streambed.

The spillway is an uncontrolled, fixed crest, ogee weir with a crest length of 72 feet at elevation 576.0 feet NGVD. The outlet works are located in the right abutment and consist of an inlet channel and a concrete weir with stoplogs to control the normal pool level.

The normal pool contains 82 acre-feet of storage for recreation and 2,310 acre-feet allocated for flood control. The flood control is equivalent to 7.7 inches of runoff from the 5.7 square mile drainage area.

8. History of Floods

a. General. Floods on the Naugatuck River may result from early spring storms combined with melting snow, such as the flood of March 1936, or from summer or fall storms such as the events of November 1927 and August 1955. In addition, local thunderstorms can cause serious flash floods on the smaller streams. The following descriptions are for the record flood of August 1955 and three of the larger events since construction of the reservoir system. Maximum reservoir levels and storage utilized at four Corps reservoirs for the June 1982, May/June 1984 and March/April 1987 floods along with the computed August 1955 and the Standard Project Flood (SPF) for the lower Naugatuck River are summarized in Table 9.

b. August 1955. The storm of August 1955 resulted in the flood of record on the Naugatuck River and was caused by heavy rainfall on ground already saturated from hurricane "Connie," which occurred during the previous week. Total precipitation recorded at Cream Hill and Torrington, CT for the period 17-20 August was 9.6 and 13.3 inches, respectively. Total runoff of the Naugatuck River at Naugatuck for the period 18-23 August was 11.9 inches from the contributing 246-square mile drainage area. Peak discharges on the Naugatuck River at Thomaston and Beacon Falls were 53,400 cfs and 106,000 cfs, respectively. This flooding occurred prior to construction of the reservoir system; however, analysis of this flood determined the maximum reservoir levels and storage utilized for a recurrence of this flood event as shown in Table 9.

c. June 1982. On 5-6 June, an intense storm deposited heavy rainfall over the State of Connecticut. Total precipitation in the watershed amounted to 10 inches. The Naugatuck River stage at Beacon Falls was 13.1 feet and the discharge was 16,000 cfs. This flood

TABLE 9

RESERVOIR STORAGE UTILIZED AND MAXIMUM POOL ELEVATIONS
FOR HISTORIC AND STANDARD PROJECT FLOODS

	Thomaston Dam	Black Rock Lake	Hancock Brook Lake	Northfield Brook Lake
Spillway Crest Elev. (ft. NVGD)	494	520	484	576
		AUGUST 1955 FLOOD		
Storage Utilized				
Acre-ft.	36,000	9,100	4,200	2,000
% of total	86	100	100	85
Inches	7.0	8.3	6.5	6.40
Max. Elev.	487.0	522.5	485.6	570.3
		JUNE 1982 FLOOD		
Storage Utilized				
Acre-ft.	14,210	4,315	2,285	690
% of total	35	50	59	60
Inches	2.7	4.0	3.6	2.27
Max. Elev.	455.4	494.5	477.4	520.1
		MAY/JUNE 1984 FLOOD		
Storage Utilized				
Acre-ft.	20,810	5,600	1,300	935
% of total	50	65	33	40
Inches	4.0	5.1	2.8	3.06
Max. Elev.	442.0	503.4	472.3	547.4
		MARCH/APRIL 1987 FLOOD		
Storage Utilized				
Acre-ft.	14,300	3,600	1,400	750
% of total	34	41	37	32
Inches	2.7	3.6	2.2	2.5
Max. Elev.	455.6	489.0	473.0	542.0
		SPF		
Storage Utilized				
Acre-ft.	34,000	9,100	4,800	2,500
% of total	81	100	100	100
Inches	6.5	8.3	7.5	8.2
Max. Elev.	484.5	522.5	487.4	577.4

resulted in utilization of storages ranging from 35 to 60 percent of capacity at Naugatuck River flood control projects.

d. May/June 1984. During the last week of May a large, slow moving storm system passed through New England bringing rainfall on Memorial Day that continued for approximately a week. Precipitation amounts varied from 8 to 9 inches in Massachusetts and Connecticut. Peak discharge on the Naugatuck River at Beacon Falls was 5,900 cfs.

Due to the continuing precipitation and extended length of time the flood control gates at Corps dams were closed, stored floodwaters rose to record levels at reservoirs within the Naugatuck River watershed. Flood regulation at Thomaston Dam resulted in a peak stage of 87.2 feet with 50 percent of its storage utilized, equivalent to 4 inches of watershed runoff. Total rainfall at the dam for the 6-day storm was 8 inches.

e. March/April 1987. During a one-week period starting at the end of March, a pair of intense rainstorms hit most of New England, causing major flooding in Connecticut, Massachusetts, New Hampshire, Vermont, and Maine. These two storms, augmented by snowmelt in the mountains and northern areas, resulted in widespread flooding. On 31 March, a fast moving storm system buffeted the entire New England area with heavy rainfall, strong southerly winds, and temperatures in the fifties and sixties. The storm system deposited 3 to 5 inches of rain in southern and coastal areas.

On 4 April, another intense but slow moving storm hit southern and most of central New England with 4 to 7 inches of rainfall. This 4-day storm created a classic one-two flood punch. Flood regulation at Thomaston Dam resulted in a peak stage of 75.6 feet, with 34 percent of its reservoir storage utilized, equivalent to 3 inches of watershed runoff. Total rainfall at Thomaston for the two storms was 8 inches.

9. Impact of Storage Encroachment

a. General. To address possible flooding impacts of seasonal encroachment into flood storage, severe historic and a synthetic flood event were analyzed. The August 1955 flood of record was the largest within the Naugatuck watershed. This event resulted from more than 13 inches of rainfall in a 48-hour period, with high antecedent moisture conditions and, therefore, was selected for analysis along with the standard project flood (SPF) for the lower Naugatuck River watershed.

The SPF developed for the Naugatuck River was based on the standard project storm (SPS) rainfall as described in Civil Engineering Bulletin 52. The SPS is defined as the most severe flood-producing rainfall depth-area-duration relationship and isohyetal pattern of any storm that is considered reasonably characteristic of the region where the drainage basin is located. A standard project flood was developed at selected downstream points for the lower Naugatuck River Basin below Thomaston Reservoir by centering the standard project storm over the lower Naugatuck River Basin and routing the flood hydrographs downstream. The resulting natural SPF at the Watertown/Waterbury local protection was 97,000 cfs and reduced to 30,000 cfs by the upstream reservoir system.

TABLE 10

NAUGATUCK RIVER WATERSHED
FLOOD ANALYSIS SUMMARY
AUGUST 1955 FLOOD

	Initial Storage (acre-ft)	Peak Inflow (cfs)	Peak Outflow (cfs)	Infringement Into Flood Control Storage (inch runoff)	Max. Pool Level (ft, NGVD)	Peak Discharge Waterbury, CT (cfs)
Thomaston Dam	10	42,500	3,500	0.0	487.7	23,500
Spillway Crest	4,000	42,500	3,500	0.8	489.2	23,500
Elevation	6,000	42,500	3,500	1.2	492.6	23,500
(494 ft, NGVD)	8,000	42,500	3,500	1.6	493.9	23,500
Black Rock	0	9,200	2,230	0.0	522.4	23,500
Spillway Crest	300	9,200	2,660	0.3	523.4	23,500
Elevation	800	9,200	2,850	0.7	523.8	23,500
(520 ft, NGVD)						
Hancock Brook	0	6,200	820	0.0	485.4	23,500
Spillway Crest	130	6,200	860	0.2	485.5	23,500
Elevation	330	6,200	930	0.5	485.6	23,500
(484 ft, NGVD)						
Northfield Brook	0	3,170	160	0.0	570.5	23,500
Spillway Crest	80	3,170	170	0.3	571.6	23,500
Elevation	480	3,170	260	1.8	576.0	23,500
(576 ft, NGVD)						

TABLE 11

NAUGATUCK RIVER WATERSHED
FLOOD ANALYSIS SUMMARY
STANDARD PROJECT FLOOD

	Initial Storage (acre-ft)	Peak Inflow (cfs)	Peak Outflow (cfs)	Infringement Into Flood Control Storage (inch runoff)	Max. Pool Level (ft, NGVD)	Peak Discharge Waterbury, CT (cfs)
Thomaston Dam	10	52,000	3,500	0.0	484.5	40,000
Spillway Crest	2,000	52,000	3,500	0.4	489.2	40,000
Elevation	4,000	52,000	3,500	0.8	491.0	40,000
(494 ft, NGVD)	6,000	52,000	3,500	1.2	491.7	40,000
	7,500	52,000	3,500	1.6	493.6	40,000
Black Rock	0	17,800	2,300	0.0	522.5	40,000
Spillway Crest	300	17,800	2,700	0.3	523.5	40,000
Elevation	800	17,800	3,940	0.7	524.2	40,000
(520 ft, NGVD)						
Hancock Brook	0	11,400	2,530	0.0	487.9	40,000
Spillway Crest	130	11,400	2,540	0.2	487.9	40,000
Elevation	330	11,400	3,090	0.5	488.0	40,000
(484 ft, NGVD)						
Northfield Brook	0	5,130	590	0.0	577.3	40,000
Spillway Crest	80	5,130	620	0.3	577.5	40,000
(576 ft, NGVD)	320	5,130	820	1.0	578.3	40,000

The natural peak of the SPF at Ansonia/Derby is 148,000 cfs and is reduced to 75,000 cfs by the upstream reservoir system. The August 1955 and SPF flood analyses for the lower Naugatuck River are shown graphically on Plates 7 and 8, respectively.

b. Procedure. Inflow hydrographs of the August 1955 flood and SPF were routed through the four lower Naugatuck River reservoir projects, using the HEC-1 computer program. This analysis was conducted with various initial storage levels and established regulation procedures to determine the resulting maximum reservoir stage (storage utilized) and outflow. This analysis was necessary to determine any allowable seasonal infringement on flood control storage to assure that no significant impact would occur on flood control capability. The assumption adopted was that any seasonal infringement that would not appreciably make downstream flooding worse or adversely affect design conditions at downstream local protection projects, for floods of the magnitude analyzed, would be considered for flow augmentation purposes.

Reallocation of reservoir storage that would have a significant effect on other authorized purposes of the project or that would involve major structural or operational changes requires Congressional approval. If the above criteria are not violated, 15 percent of total storage capacity allocated to all authorized Federal purposes, up to 50,000 acre-feet, may be allocated from the storage within the Chief of Engineers discretionary authority. For purpose of this study, the upper limit of 15 percent total storage was adopted in general compliance with Corps policy as stated in EP 1165-2-1, dated February 1989.

c. Results. Results of the analysis are shown in Tables 10 and 11 and are discussed below:

Thomaston Dam

The results of the analyses indicate that the maximum allowable storage of 15 percent can be utilized at Thomaston before adversely affecting downstream flooding. Analysis of the August 1955 and SPF events demonstrates that 6,000 acre-feet, equivalent to 1.2 inches of runoff from the 97.2 square mile drainage and 1.5 inches from the 75.7 square mile net drainage area, could be utilized without experiencing spillway discharge for these two extreme flood events. Utilizing 6,000 acre-feet of storage would result in a pool with a maximum depth of 56 feet and surface area of 300 acres.

Black Rock Lake

Black Rock has a flood control storage capacity of 8,450 acre-feet, equivalent to 7.7 inches of runoff. In a recurrence of the August 1955 flood or in the event an SPF, spillway surcharge would be about 2.5 feet for both flood events. An encroachment into flood control storage of 0.2 inch (200 acre-feet) of runoff would result in a minor increase in spillway discharge for the August 1955 and SPF events. Due to desynchronization, these discharges would not contribute to main stem flows. The remaining available storage at Black Rock would be 7.5 inches of runoff affording control over the vast majority of flood events. Therefore, 0.2 inch (200 acre-feet) of encroachment could be utilized at Black Rock Lake.

Hancock Brook

Hancock Brook has a flood control storage capacity of 3,900 acre-feet, equivalent to 6.1 inches of runoff. In a recurrence of the August 1955 flood or in the event of an SPF, spillway surcharge would be 1.4 and 3.9 feet for these two flood events, respectively. An encroachment into flood control storage of 0.2 inch of runoff would only slightly increase spillway surcharge and outflow for the two events analyzed; however, it would result in an available flood control storage of 5.9 inches. This storage for the watershed was judged unacceptable due to the magnitude of experienced flood events.

Northfield Brook

Northfield Brook, an unmanned dam, has a flood control storage capacity of 2,350 acre-feet, equivalent to 7.7 inches of runoff. Analysis indicates that Northfield Brook dam would not experience spillway discharge in a recurrence of the August 1955 flood and, in fact, significant encroachment into storage could be permitted prior to experiencing spillway discharge. Analysis of the SPF, however, indicates that with no encroachment into flood control storage, a spillway surcharge of about 1.3 feet would occur with a resulting outflow of 590 cfs. A 0.3-inch encroachment would result in only slightly increasing spillway surcharge (0.2 foot) with a resulting 5 percent increase in outflow. A 0.3-inch encroachment would result in 7.4 inches of available flood control storage and 80 acre-feet for flow augmentation. Therefore, 0.3 inch (80 acre-feet) of encroachment appears reasonable and can be provided at Northfield Brook.

10. Effects of Reallocated Storage on Streamflow

It has been determined that a significant portion of the flood control storage at Thomaston Dam could be utilized for streamflow augmentation without adversely impacting its flood control function. Seasonal use of 6,000 acre-feet (15 percent of total storage) would result in a pool elevation of about 436 feet NGVD (56-foot stage).

This seasonal pool would result in an additional average release of about 25 cfs daily over a 120-day period (June to September). The effect of this release is shown on the flow duration curve. It is estimated that the increased streamflow would not have a significant affect on streamflow depths (less than 0.5 foot) at Waterbury, however, releases from Thomaston Dam can have a significant effect on relative streamflow rates and volumes at Waterbury during the June to September time period. Summer flows at Waterbury are less than 42 cfs 10 percent of the time. The additional 25 cfs from Thomaston storage represent a 60 percent increase and, as can be seen on the flow duration curves on Plate 9, would represent a significant increase over the entire range of summer flows. In addition, the estimated 7-day, 10-year summer season low flow at Waterbury is 34 cfs and an additional 25 cfs discharge from Thomaston would represent a 70 percent increase to this low flow.

Analyses at Black Rock and Northfield Brook Lakes indicates that storage of 200 and 80-acre feet, respectively, could be utilized to augment streamflows. These storages combined would result in additional daily summer flows of about 1 cfs. This small increase in streamflow would result in only a slight increase in stream depths at Waterbury. Therefore, storage at these Corps facilities for flow augmentation purposes has not been considered further in this report.

11. Reservoir Filling

It is assumed that the seasonal pool contemplated behind Thomaston Dam would be filled primarily during the month of May. An analysis of streamflow volumes available from the Naugatuck River at Thomaston during May was conducted to assure that the pool could be filled even during dry years.

Analysis of low flow records as recorded by the USGS at Thomaston indicates the lowest May flow on record occurred in 1965 during the "1960's drought." The recorded mean monthly flow was 75 cfs (0.77 csm), and preceded by a low April of 159 cfs (1.6 csm). For comparison purposes, the average April and May flows are 402 and 202 cfs, respectively. Analysis of this data indicates that assuming a downstream release rate of 0.2 csm (20 cfs) during May would have resulted in 4,400 acre-feet of storage occurring at Thomaston. In such a dry year, storage of water could begin in late April. Analysis of the April 1965 flow data indicates that with a downstream release of 0.25 csm (25 cfs), an additional 1,600 acre-feet of water could be stored in less than a one-week period. Since May 1965 was the driest May on record and preceded by a dry April, this analysis demonstrates that storage filling of 6,000 acre-feet is reasonably assured at Thomaston even during dry years. If studies are to continue, a more detailed storage filling schedule including reservoir operational procedures will have to be developed.

12. Additional Storage Impacts

There are several potential water quality and environmental impacts that could occur should a seasonal impoundment be established at the normally dry-bed flood control reservoir. These impacts should be studied in further detail and their impacts weighed against the positive aspects of the project before changes are made to the project operation.

Thomaston Dam is the prime candidate for storing water for the purpose of augmenting flows in the Naugatuck River in Waterbury. A Corps' report entitled "Drought Contingency Plan, Thomaston Dam, Thomaston, Connecticut", completed in June 1983, investigated the creation of a 28-foot permanent pool at Thomaston Dam for the purpose of providing a water supply source during drought conditions. The report concluded that the creation of a 28-foot permanent pool behind Thomaston Dam could result in the degradation of the water quality of the Naugatuck River below the dam and in the reservoir itself, and therefore storage for water supply purposes was not recommended.

The principal water quality concern would be the potential for nuisance algae blooms resulting from existing high concentrations of phosphorous in this portion of the Naugatuck River. Algae blooms could degrade the water quality in the Naugatuck River by their unsightly appearance and by the odors that could occur at night when the the dissolved oxygen (DO) was depleted. If sufficient reaeration does not occur at the outlet works, low nighttime DO levels in the river could violate State standards. Algae blooms could cause fish kills either indirectly through severe diurnal fluctuations in DO and pH levels, or directly through poisoning. Finally, algae blooms could cause anaerobic conditions in the lake bottom which would allow heavy metals such as iron and manganese to be released from the sediments.

Creating a pool at Thomaston Dam may also change the thermal regime of the river, however, the problems caused by this may be masked by the problems caused by the algae.

In addition to these water quality effects on the main stem of the Naugatuck River, the creation of a pool at Thomaston Dam could result in a possible lowering of water quality in the last mile of Leadmine Brook, a Class A water quality tributary to the Naugatuck River. This degradation could occur because of the effects of siltation on the trout habitat and associated benthic invertebrates, and because of the influx of the poorer quality water into the high quality Leadmine Brook.

Other potential impacts of creating a pool behind Thomaston Dam would be to both water and land-based recreation, and to public access facilities which would have to be relocated to higher ground. Other impacts to the project area would be the inundation of a series of off-road vehicle trails adjacent to the river, and the flooding of a field now used for the flying of remote-control model airplanes under a 15-year agreement with the Corps. In addition, if the pool level fluctuates, erosion and slumping may occur.

13. <u>Naugatuck River Ponding Assessment</u>

The State of Connecticut requested that a cursory assessment of requirements necessary to create a series of "pools" along the Naugatuck River through Waterbury be made. A river profile, developed through Waterbury based on available information, is shown on Plate 10. As can seen on Plate 10, starting at the headwaters of the pool created by Platt Brothers dam, at approximately the downstream corporate limits of Waterbury, one scenario would be of three small dams about 10 feet high. These dams would create three shallow pools through Waterbury. The dams would have to be carefully designed so as not to adversely impact flooding in Waterbury. Frther studies would have to address impacts to fish life, water quality, etc. by the dams. In addition, detailed current survey information on river invert and crest elevations of existing dams would have to be obtained.

14. Conclusions

This reconnaissance level study indicates that significant storage at Thomaston Dam could be utilized to augment Naugatuck River streamflows at Waterbury during the low flow summer months of June through September. Storage of 6,000 acre-feet could be utilized at Thomaston without experiencing spillway discharge in a recurrence of the August 1955 flood or in the event of the Standard Project Flood centered over the lower Naugatuck River basin. Release of the 6,000 acre-feet of storage over the 120-day summer season, would result in a 25 cfs daily increase in summer season streamflow. The resulting increase in stream depth at Waterbury would be less than 0.5 feet, although streamflow rates and volumes would be significantly increased.

Prior Corps of Engineers investigations have indicated that the potential exists for severe water quality and environmental impacts to occur should an impoundment be established at this normally dry-bed flood control reservoir. These impacts should be studied in further detail and their negative aspects weighed against the positive aspects of the flow augmentation project before changes are made to the project operation.

15. REFERENCES

a. U.S. Army Corps of Engineers, "Master Manual of Water Control Regulation, Housatonic River Basin, Connecticut," October, 1976.

b. U.S. Army Corps of Engineers, Northeast Flood Study, "Report on Review of Survey For Flood Control, Housatonic River Basin, Connecticut, Massachusetts, and New York," September 1963.

c. U.S. Army Corps of Engineers, Northeast Flood Studies, "Interim Report on Review of Survey, Upper Naugatuck River, Torrington, Connecticut," May, 1956.

d. U.S. Army Corps of Engineers, "Thomaston Dam, DM No. 1, Hydrology and Hydraulic Analysis," Boston, MA, 1957.

e. U.S. Interagency Advisory Committee on Water Data, Bulletin 17B, "Guideline for Determining Flood Flow Frequency," March 1982.

f. Federal Emergency Management Agency, "Flood Insurance Study for the City of Waterbury, Connecticut", November 1, 1979.

g. U.S. Army Corps of Engineers, "Torrington Local Protection Projects, Hydrologic Assessment," February 1989.

h. U.S. Army Corps of Engineers, "Drought Contingency Plan, Thomaston Dam, Thomaston, Connecticut", June 1983.

i. U.S. Army Corps of Engineers, "Hydropower Study, Reconnaissance Report, Thomaston Dam Thomaston, Connecticut", August 1982.

CORPS OF ENGINEERS U.S. ARMY

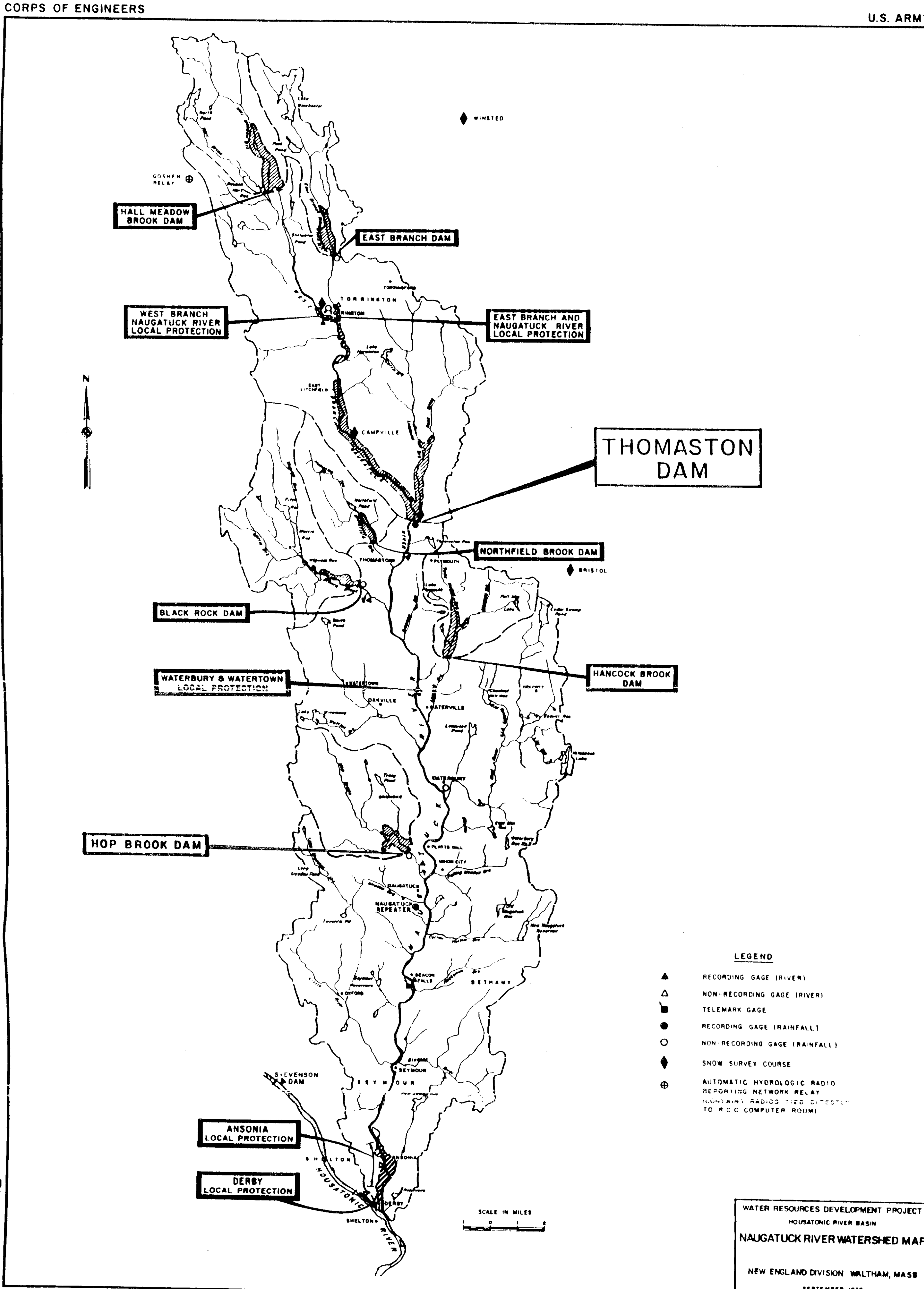
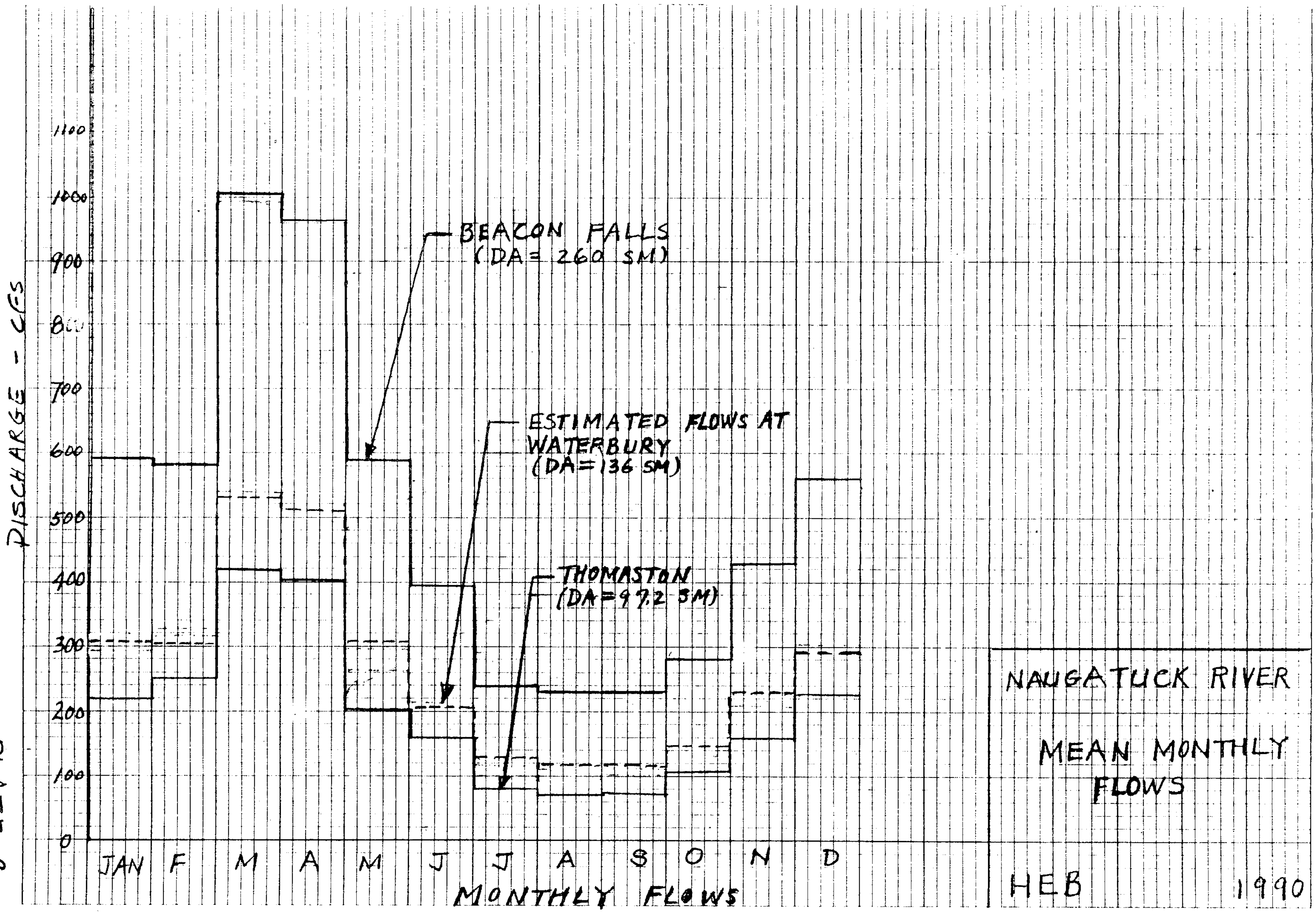
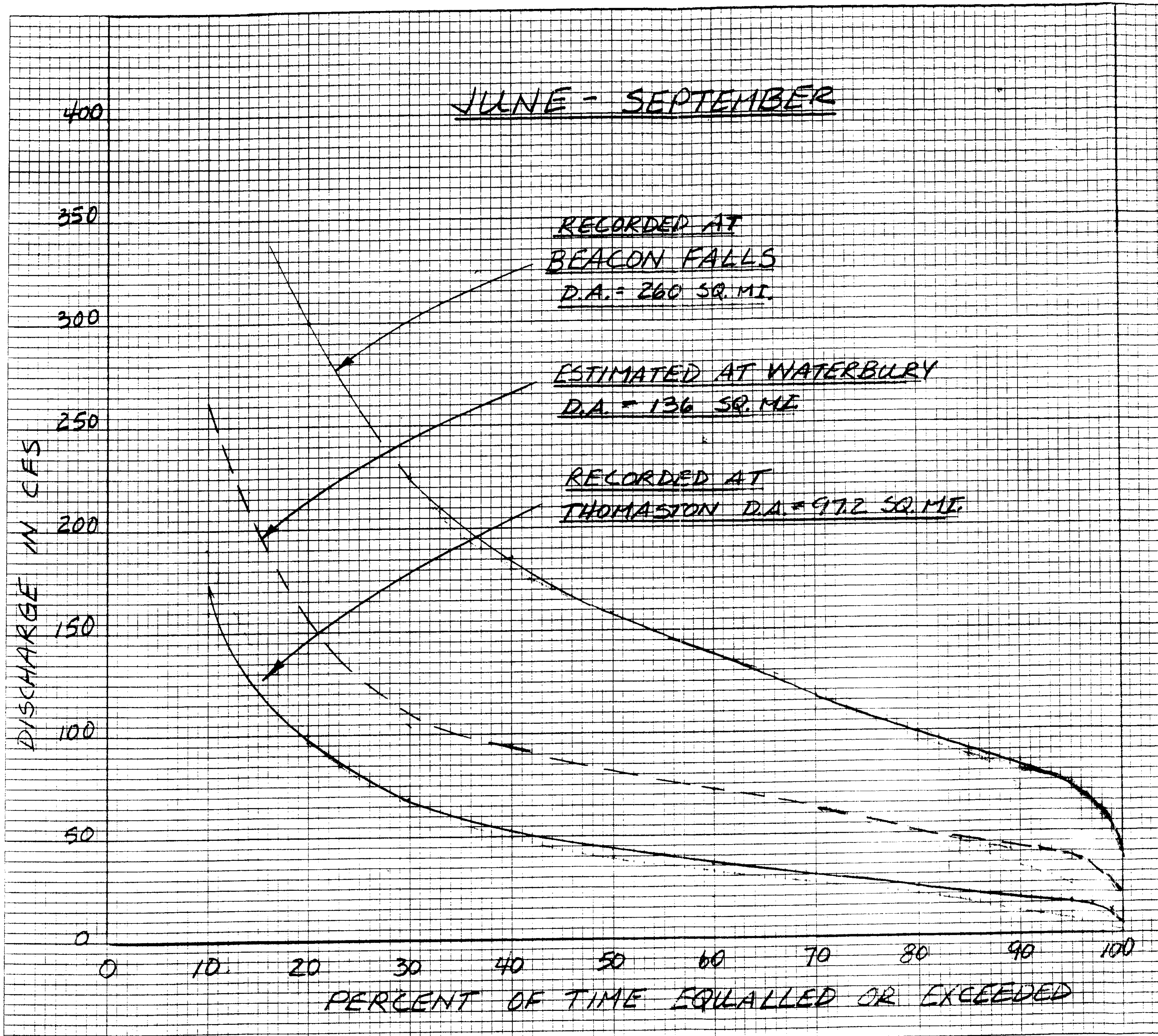


PLATE 1

PLATE 2


DISCHARGE - CFS
1100
1000
900
800
700
600
500
400
300
200
100
0
BEACON FALLS
(DA= 260 SM)
ESTIMATED FLOWS AT
WATERBURY
(DA=136 SM)
THOMASTON
(DA=97.2 SM)
JAN F M A M J J A S O N D
MONTHLY FLOWS
NAUGATUCK RIVER
MEAN MONTHLY
FLOWS
HEB
1990



NAUGATUCK RIVER CT.

JUNE - SEPTEMBER

FLOW DURATION CURVES

HEB SEPT 1990

PLATE 3

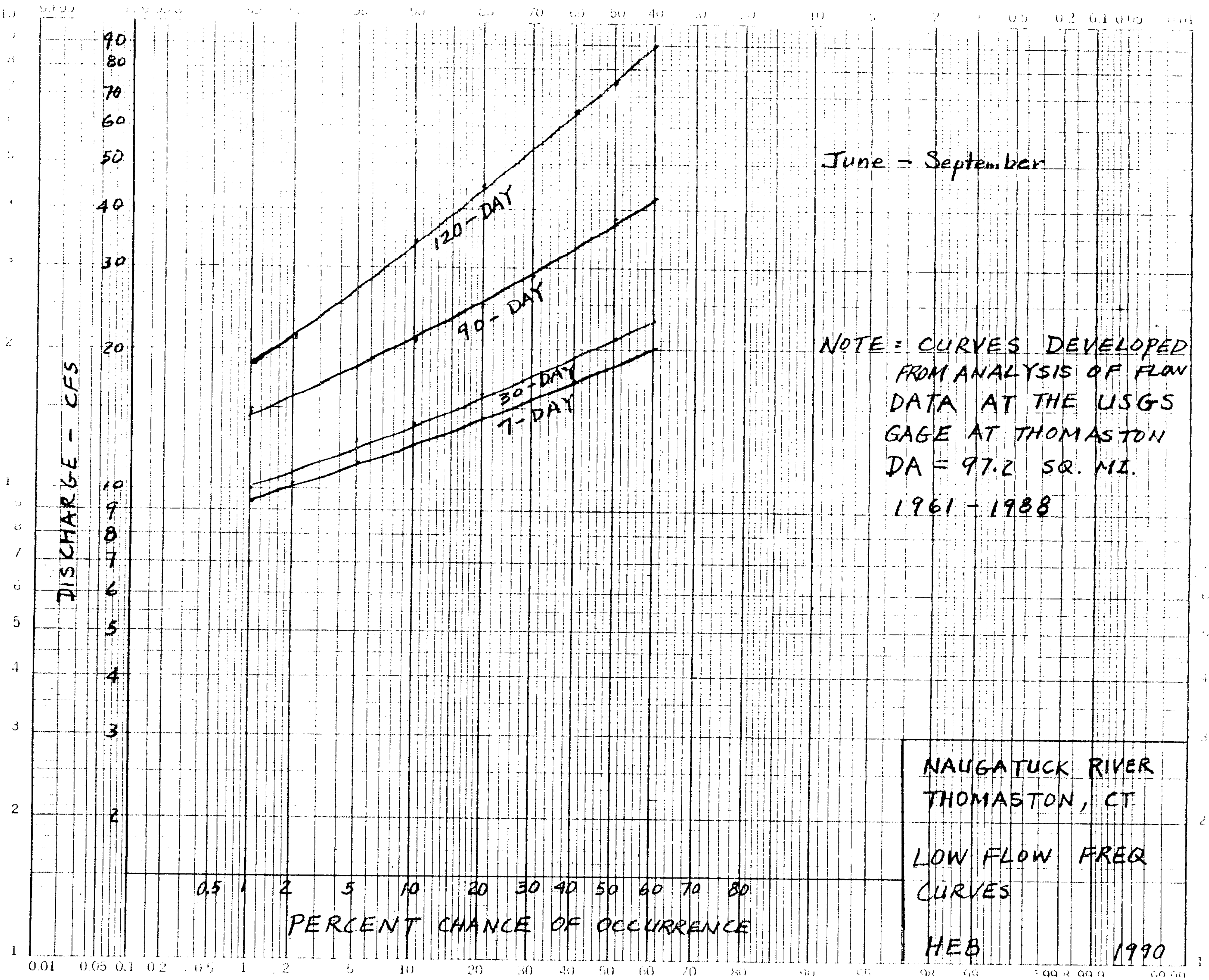

June - September
120-DAY
90-DAY
30-DAY
7-DAY
DISCHARGE - CFS
PERCENT CHANCE OF OCCURRENCE
NOTE: CURVES DEVELOPED FROM ANALYSIS OF FLOW DATA AT THE USGS GAGE AT THOMASTON
DA = 97.2 SQ. MI.
1961 - 1988
NAUGATUCK RIVER
THOMASTON, CT
LOW FLOW FREQ CURVES
HEB
1990

PLATE 4

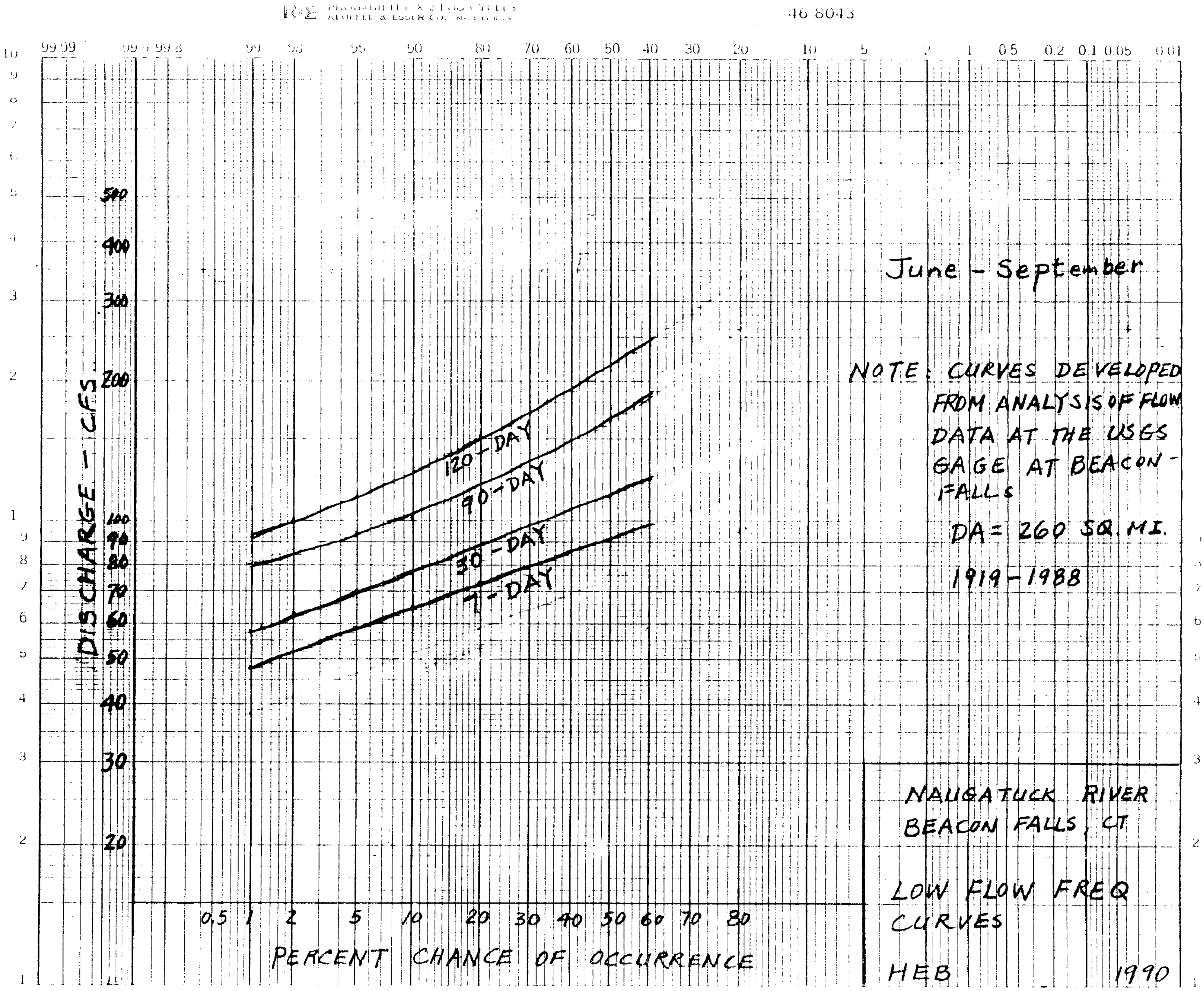

K&E PROBABILITY X 2 LOG CYCLES
KEUFFEL & ESSER CO.
46 8043
June - September
NOTE: CURVES DEVELOPED FROM ANALYSIS OF FLOW DATA AT THE USGS GAGE AT BEACON-FALLS
DA = 260 SQ. MI.
1919 - 1988
120-DAY
90-DAY
30-DAY
7-DAY
DISCHARGE - CFS
PERCENT CHANCE OF OCCURRENCE
NAUGATUCK RIVER
BEACON FALLS, CT
LOW FLOW FREQ CURVES
HEB
1990

PLATE 5

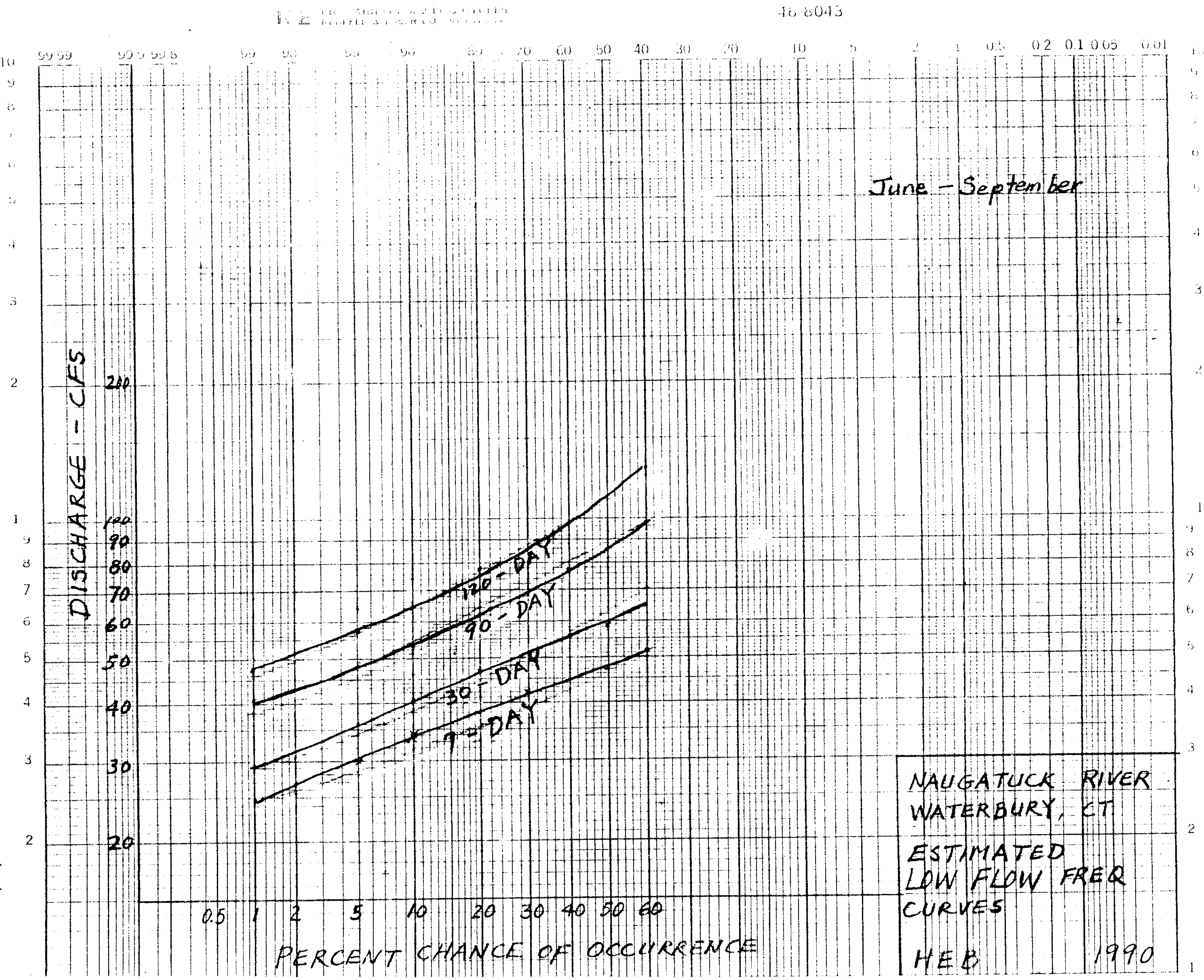
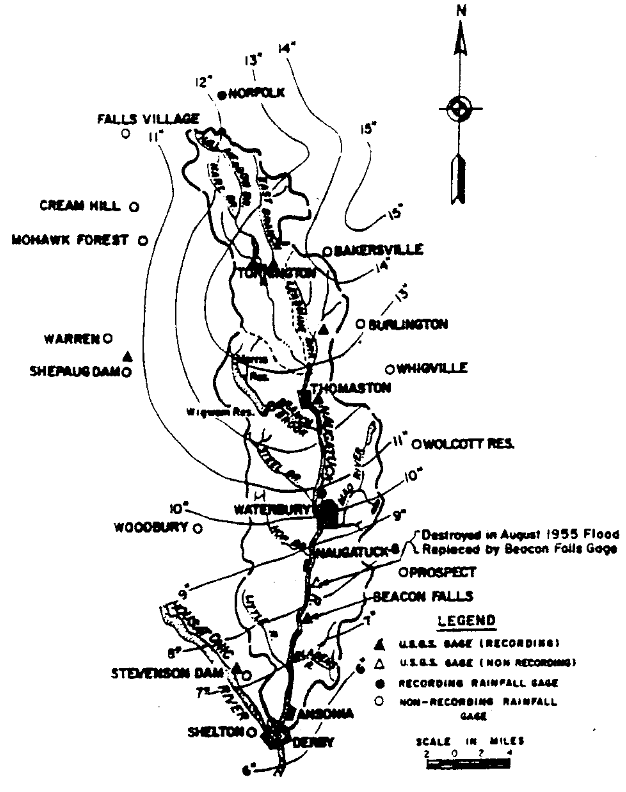
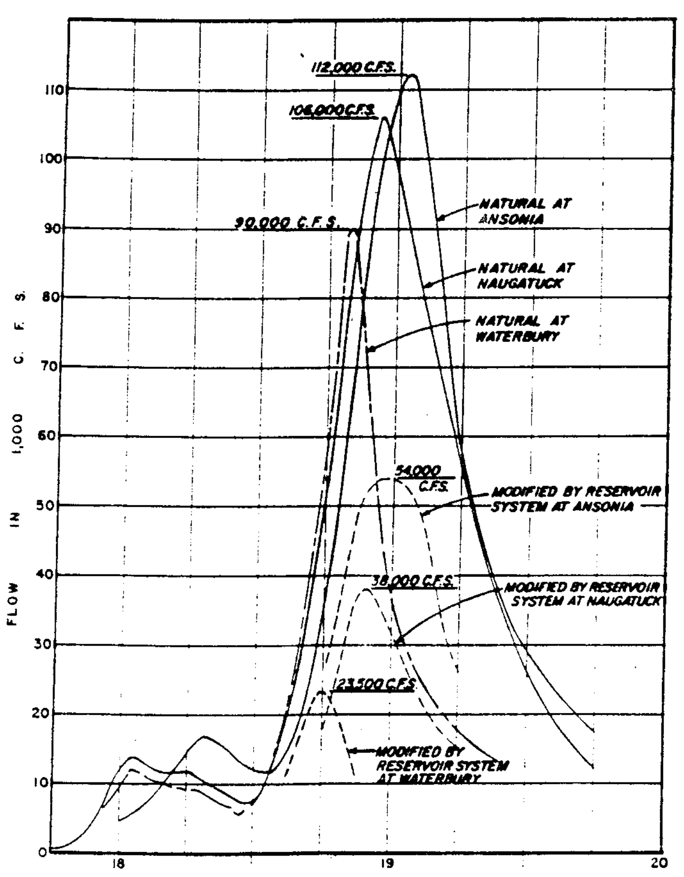

46 8043
June - September
DISCHARGE - CFS
120 - DAY
90 - DAY
30 - DAY
7 - DAY
PERCENT CHANCE OF OCCURRENCE
NAUGATUCK RIVER
WATERBURY, CT
ESTIMATED
LOW FLOW FREQ
CURVES
HEB
1990

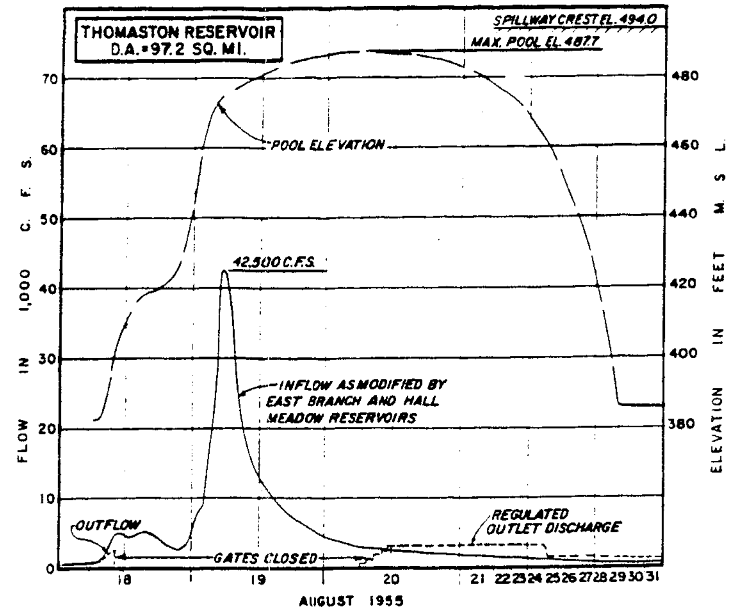
Plate 6

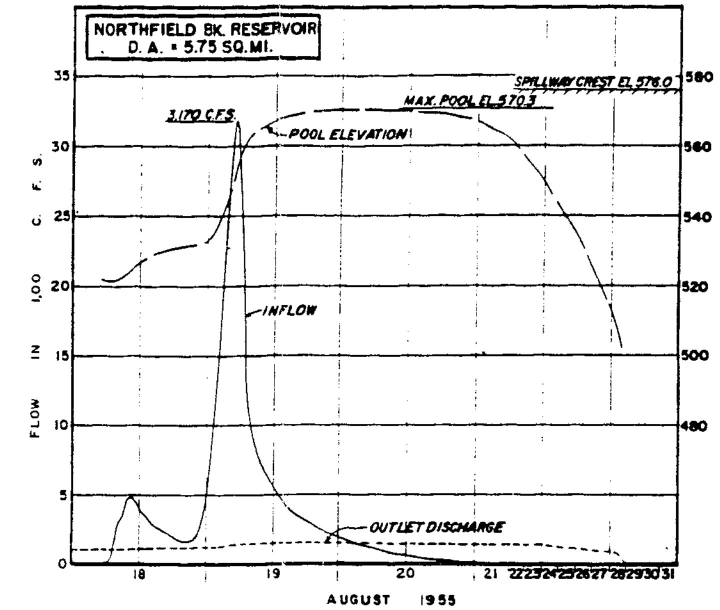
CORPS OF ENGINEERS — U. S. ARMY

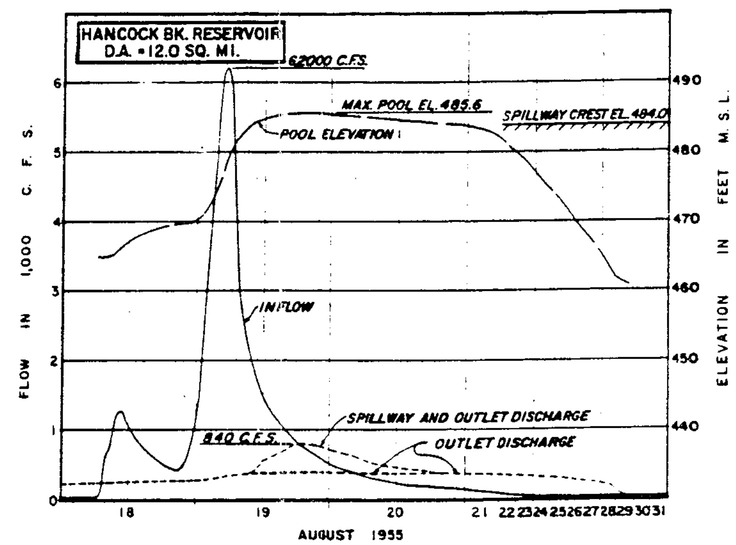


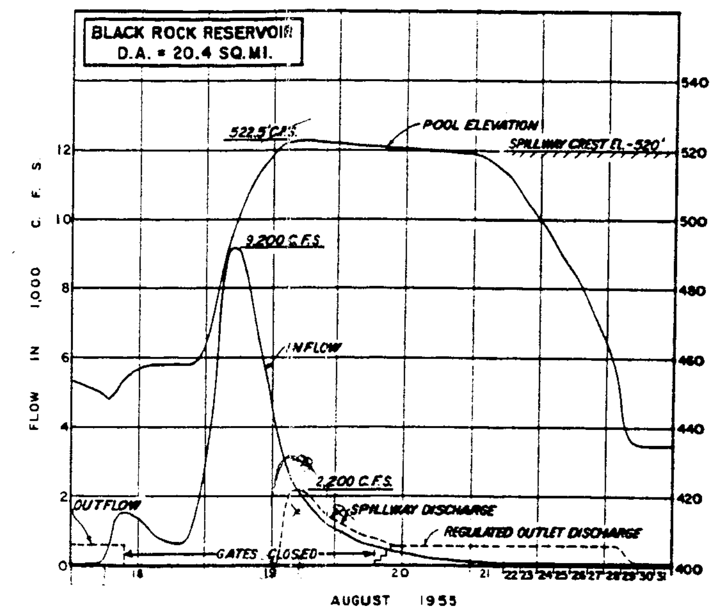
ISOHYETAL MAP
STORM OF AUGUST 17-19, 1955
NAUGATUCK RIVER BASIN

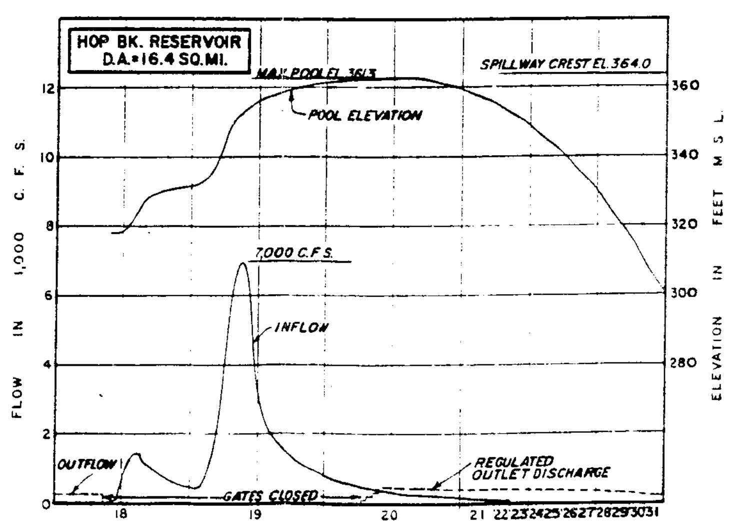












REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY — TR. BY M.W.B. — CK. BY

PROJECT ENGINEER

CHIEF, SECTION

SUBMITTED BY

CHIEF, PLANNING DEPT & BRANCH

HOUSATONIC RIVER FLOOD CONTROL

LOWER NAUGATUCK RIVER

FLOOD OF AUGUST 1955

NAUGATUCK RIVER WATERSHED, CONNECTICUT

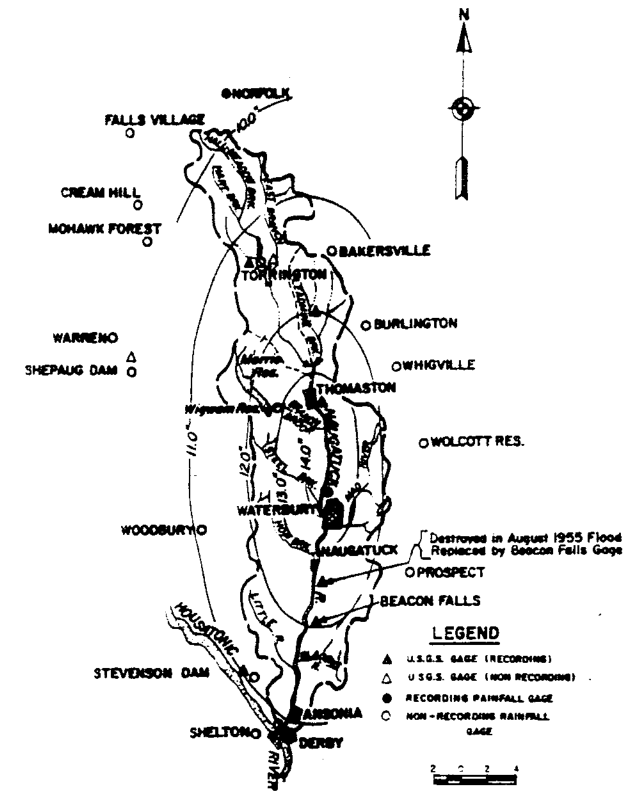
APPROVED — CHIEF ENGINEERING DIV — DATE JAN. 1964

SCALE — SPEC. NO. CIV ENG-19-016-

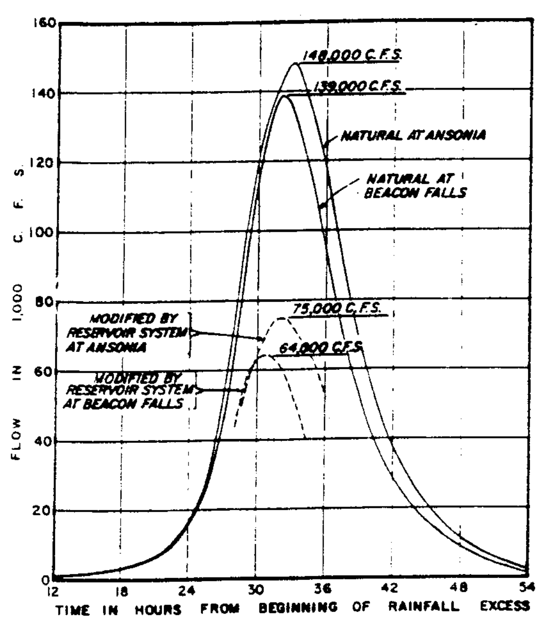
DRAWING NUMBER

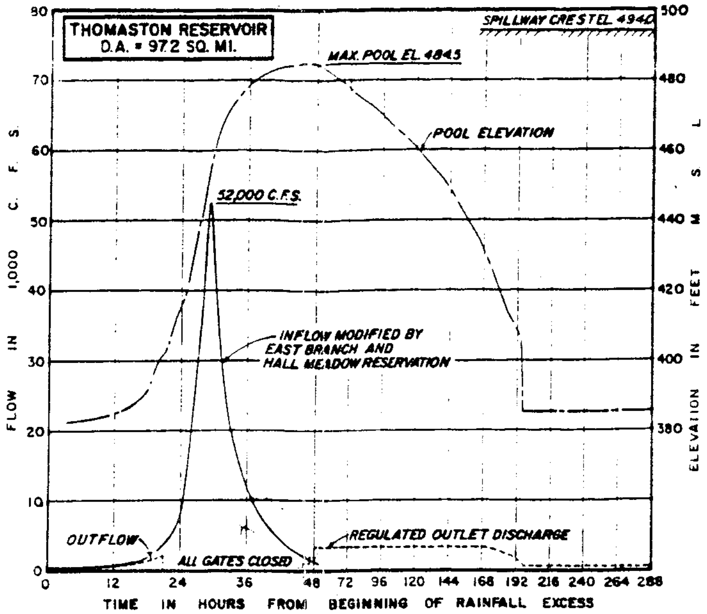
SHEET

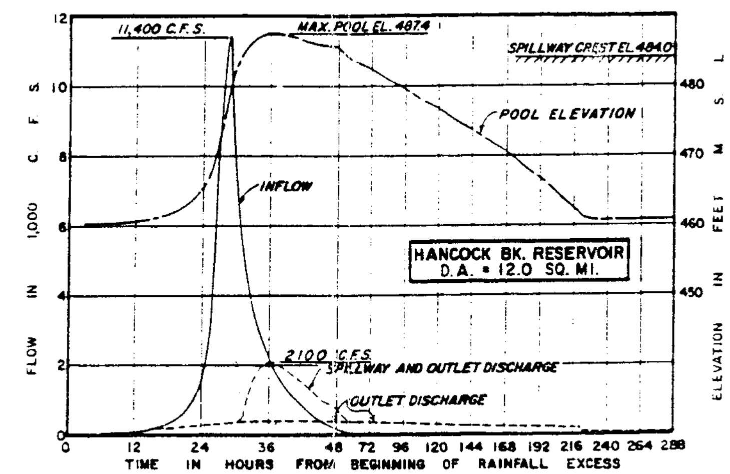
PLATE 7

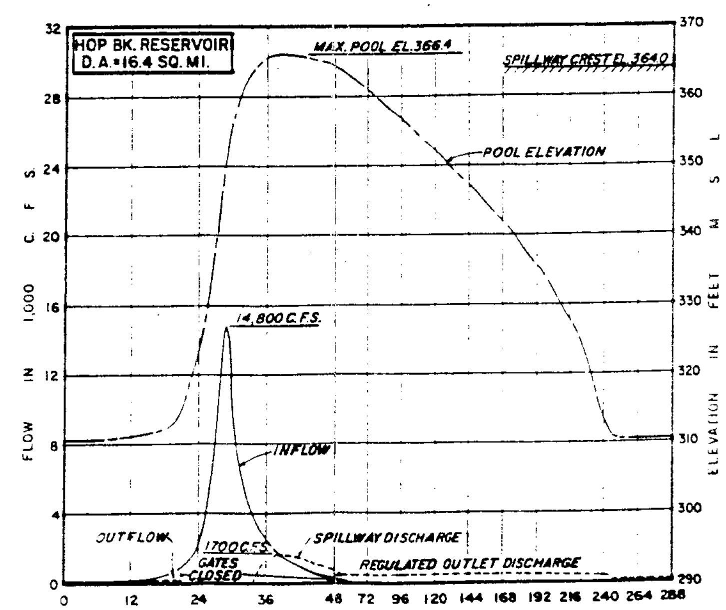


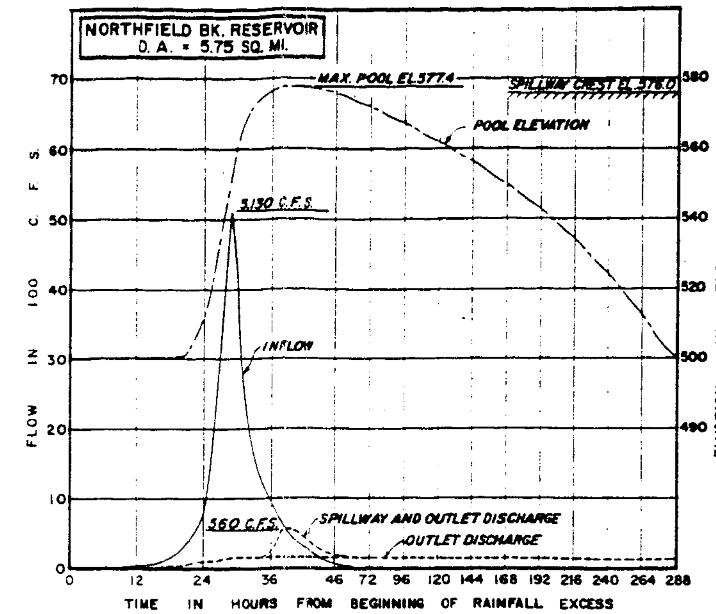
ISOHYETAL MAP
STANDARD PROJECT STORM
NAUGATUCK RIVER BASIN
96 HOUR DURATION

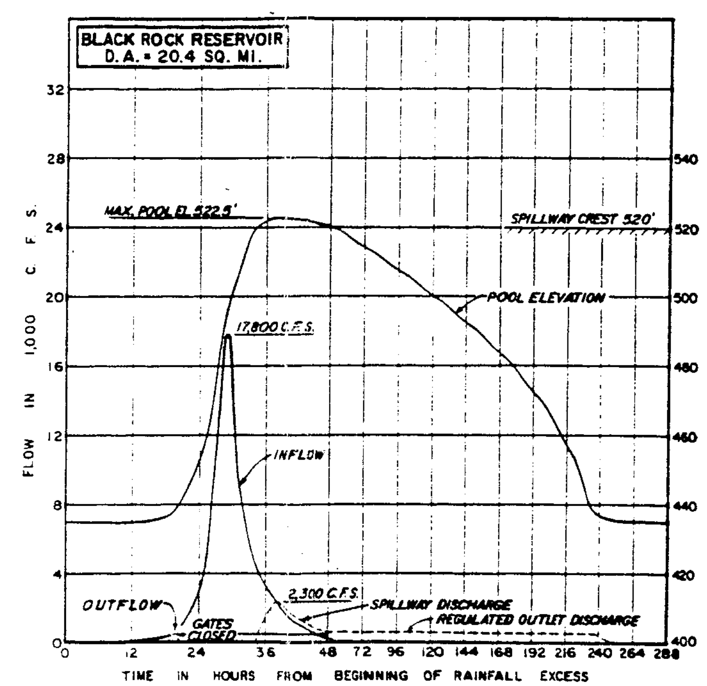












U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

HOUSATONIC RIVER FLOOD CONTROL

LOWER NAUGATUCK RIVER

STANDARD PROJECT FLOOD

NAUGATUCK RIVER WATERSHED, CONNECTICUT

DATE JAN. 1964

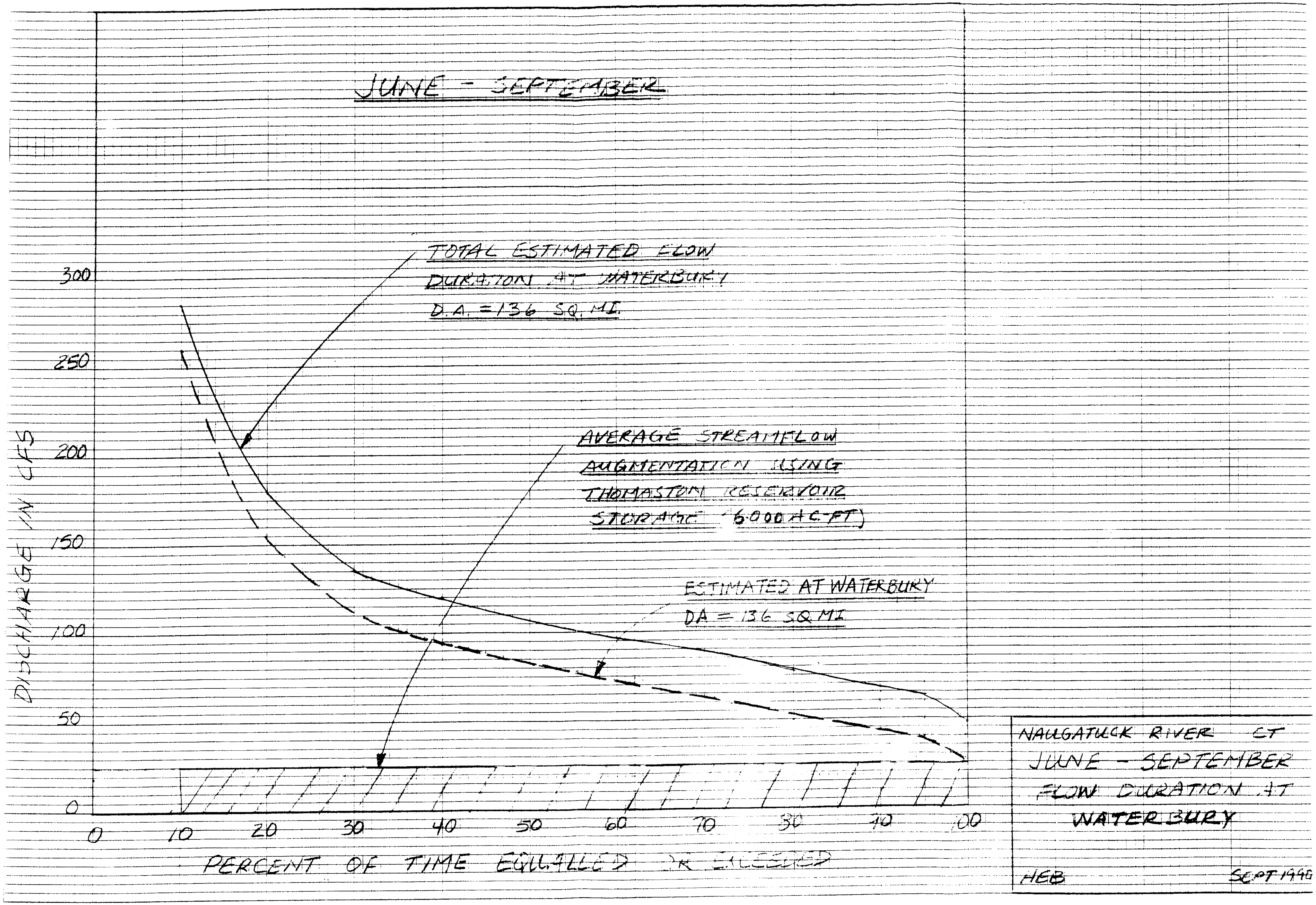
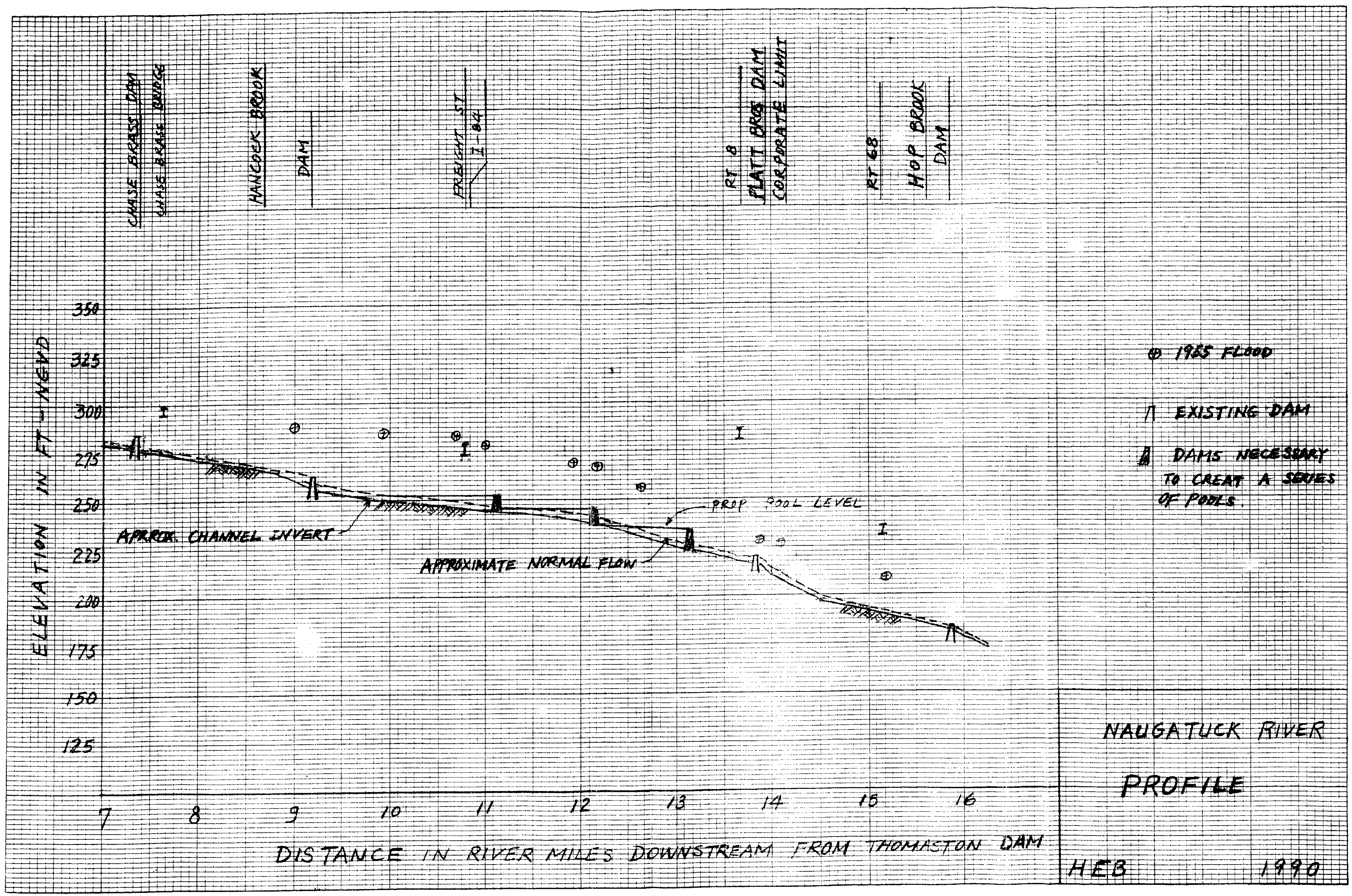

JUNE - SEPTEMBER
TOTAL ESTIMATED FLOW
DURATION AT WATERBURY
D.A. = 136 SQ. MI.
AVERAGE STREAMFLOW
AUGMENTATION USING
THOMASTON RESERVOIR
STORAGE (6000 AC-FT)
ESTIMATED AT WATERBURY
DA = 136 SQ MI
DISCHARGE IN CFS
300
250
200
150
100
50
0
0
10
20
30
40
50
60
70
80
90
100
PERCENT OF TIME EQUALLED OR EXCEEDED
NAUGATUCK RIVER CT
JUNE - SEPTEMBER
FLOW DURATION AT
WATERBURY
HEB
SEPT 1990

PLATE 9



CHASE BRASS DAM
CHASE BRASS BRIDGE
HANCOCK BROOK
DAM
FREIGHT ST
I-84
RT 8
PLATT BROS DAM
CORPORATE LIMIT
RT 68
HOP BROOK
DAM
ELEVATION IN FT - NGVD
350
325
300
275
250
225
200
175
150
125
APPROX. CHANNEL INVERT
APPROXIMATE NORMAL FLOW
PROP. POOL LEVEL
1955 FLOOD
EXISTING DAM
DAMS NECESSARY TO CREAT A SERIES OF POOLS.
7
8
9
10
11
12
13
14
15
16
DISTANCE IN RIVER MILES DOWNSTREAM FROM THOMASTON DAM
NAUGATUCK RIVER
PROFILE
HEB
1990

Plate 10